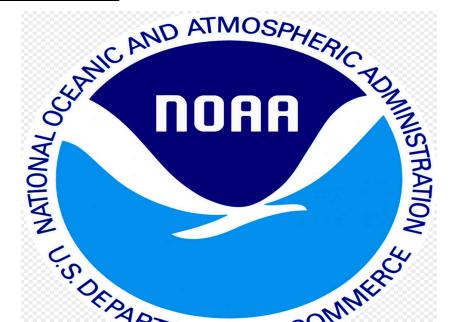
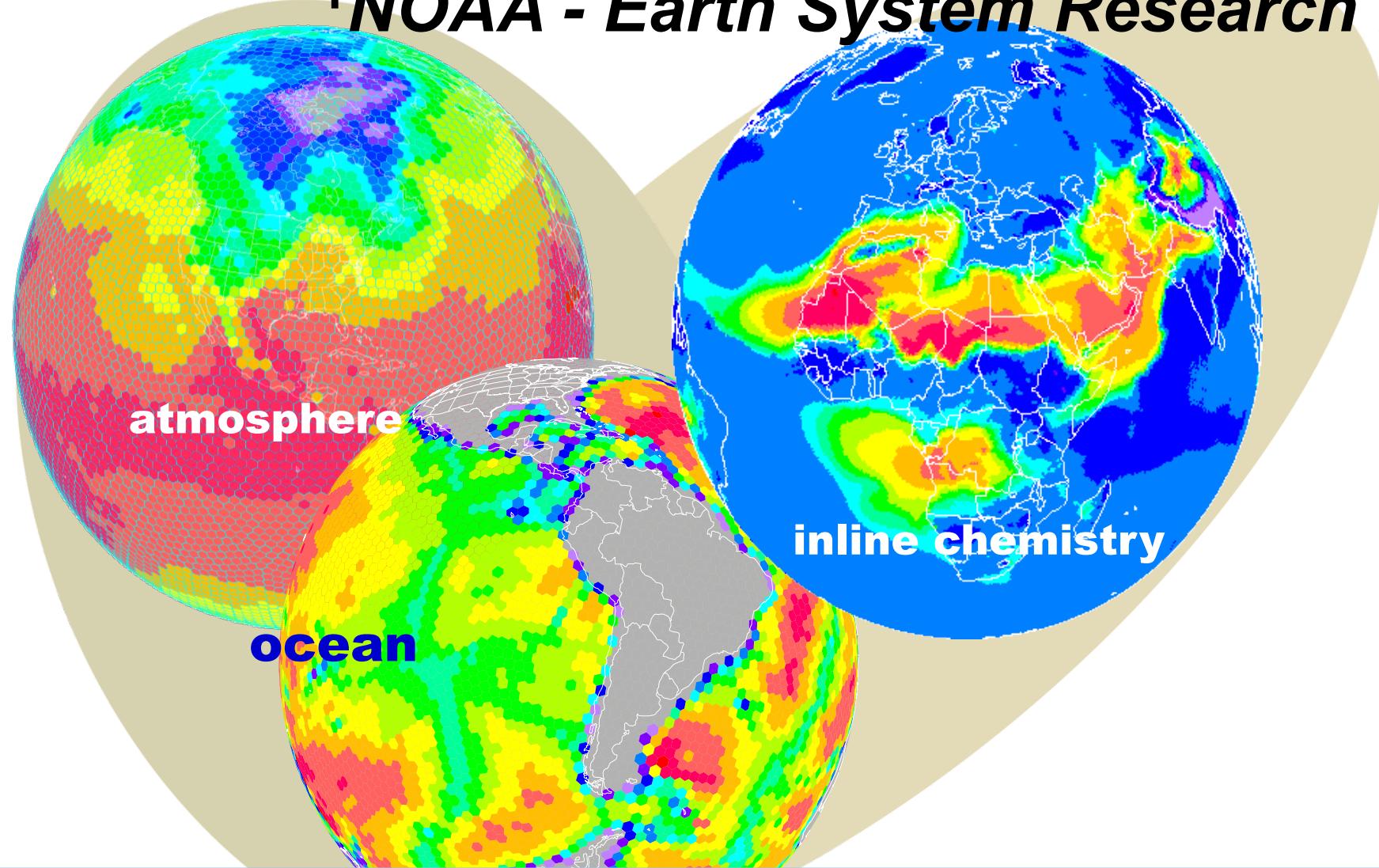


Development and experiments with FIM-iHYCOM coupled atmos-ocean-chem global model for seasonal to medium-range forecast applications



Stan Benjamin¹, Shan Sun^{1,2}, Rainer Bleck^{1,2,3}, Haiqin Li^{1,2}, Georg Grell¹, Jian-Wen Bao¹, John M. Brown¹

¹NOAA - Earth System Research Laboratory, Boulder, CO USA ²CIRES, Univ. of Colorado ³NASA Goddard Institute for Space Studies



Development of Earth System Models for All Time-Scales

Increased application of coupling to ocean models and inline chemistry is expected for global numerical weather prediction from seasonal to short-range (<12h) scales for improved cloud/precipitation/air-quality forecasts for aviation, energy, transportation, air quality, and severe weather applications. NOAA-ESRL (with partners) has developed a fully coupled atmos-ocean-chem model (FIM-iHYCOM-chem).

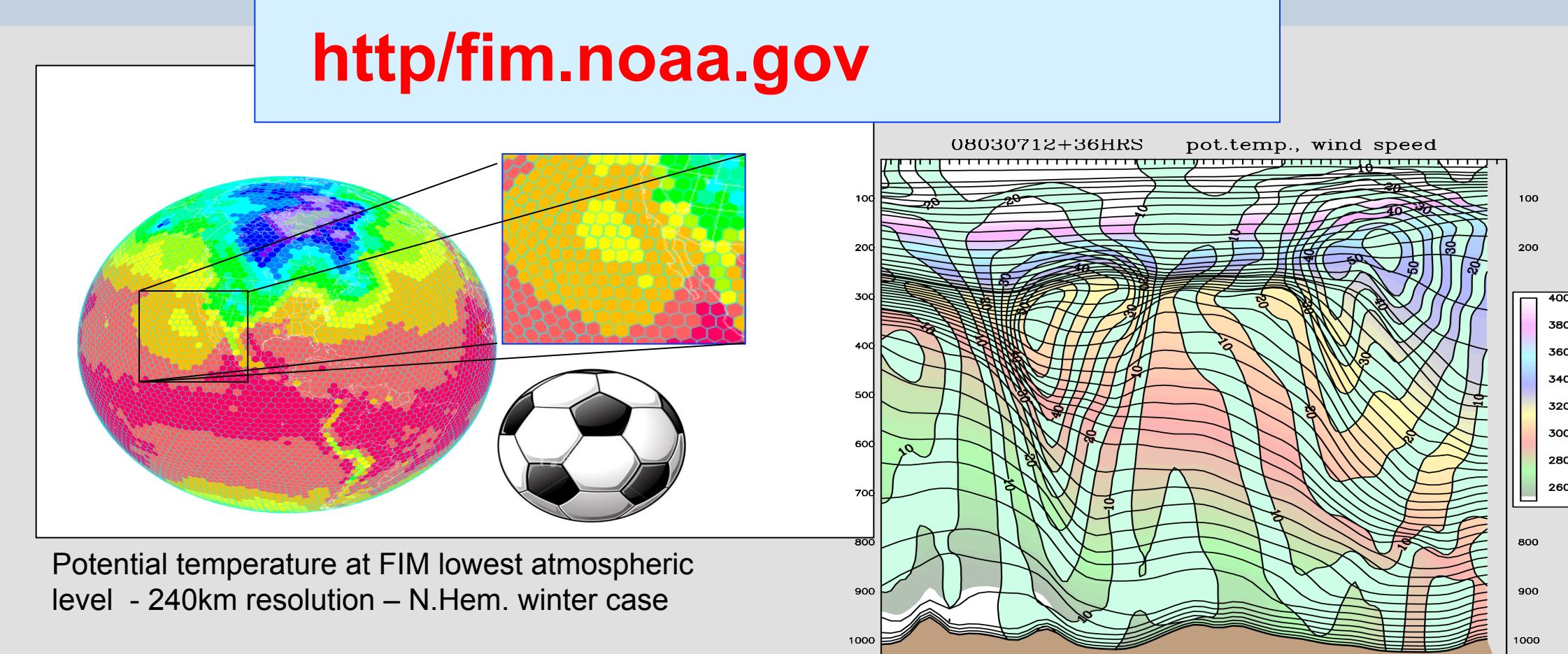
FIM earth system model components

Atmosphere

The Flow-following Finite-volume Icosahedral Model – FIM

Combination of 3 numerical design advantages

- **Icosahedral** horizontal grid ("I" in FIM)
- **Isentropic-sigma hybrid vertical coordinate** ("F" for "flow-following" in FIM) – primary option, sigma-pres coord also available.
- Physics from NOAA/NCEP GFS model (chem exception below)
- Running in real-time at NOAA/ESRL at 60/30/15/10km horizontal resolution (atmos and atmos/chem only)



<http://fim.noaa.gov>

Aspects of FIM's hybrid θ - σ vertical coordinate.

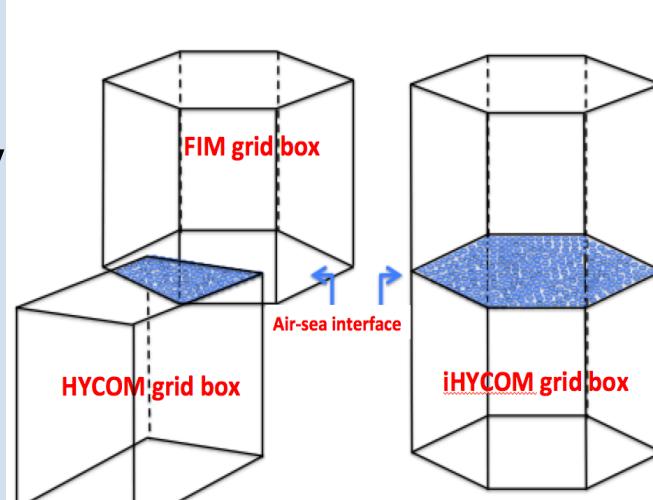
- In free atmosphere, color follows coordinate layers, indicating that layers are isentropic (constant θ). Near ground, layers follow the terrain (constant σ).
- Strengths of hybrid isentropic-sigma coordinate:
 - Adaptive vertical resolution of fronts
 - Reduced cross-coordinate transport (Johnson et al. 2002, J. Climate), reduced vertical numerical diffusion, improved PV conservation

Ocean

iHYCOM – icosahedral ocean model

HYCOM rewritten for icosahedral grid.

Otherwise, same as US Navy/NOAA community Hybrid Community Ocean Model (HYCOM)



- Hybrid quasi-Lagrangian vertical coordinate (isopycnal/sigma), adaptive similar to FIM atmos
- Shares multiprocessor environment, numerics for unstructured grid with FIM. Called as subroutine.
- Common 1-1 grid eliminates interpolation for air-sea fluxes.
- First fully-coupled global atmos-ocean model for NOAA using HYCOM

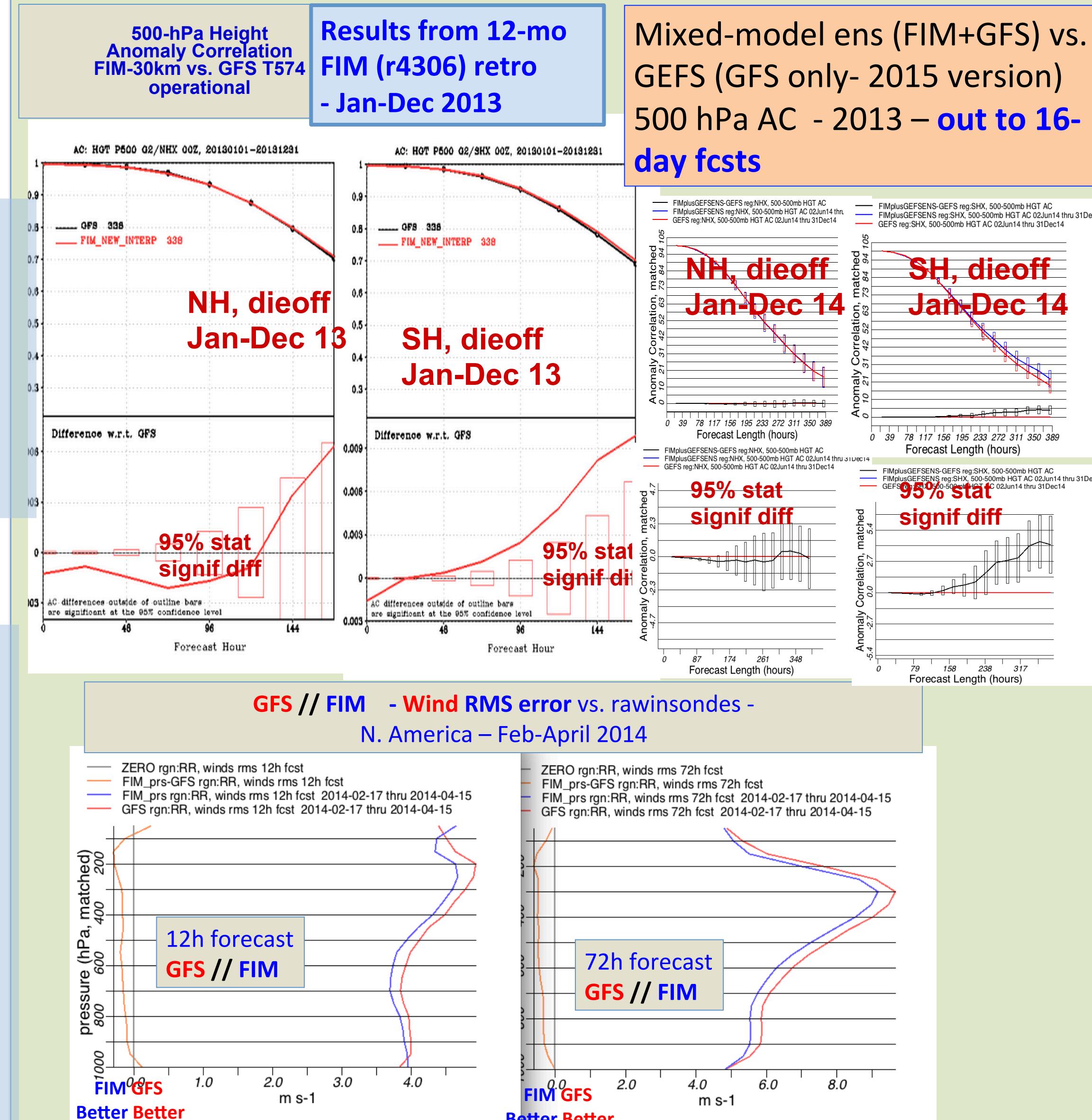
Chemistry FIM-chem options

- Aerosol and simple sulfur chemistry modules from the Global Chemistry Aerosol Radiation and Transport (GOCART) model
- 4-bin sea-salt from GOCART
- 5-bin dust based on GOCART but after further development from AER/AFWA
- Wildfire plume-rise
- Volcanic ash and SO2 emissions, historic or in real-time
- Dry and wet deposition, sub-grid scale transport
- Aerosol direct & semi-direct effect through interaction w/ radiation (online Mie)
- Mass-flux mixing (via Grell-Freitas)

	init condns	Resolution	Horiz. Representation	Vertical coord	Physics
GFS	GFS	T574 to 8d, T382 to 16d (Next version to T1534)	Spectral	Sigma-pressure hybrid	GFS suite
FIM	GFS	60km/30km/15km/10km	Icosahedral grid point	Isentropic-sigma hybrid	GFS suite, 2011 version, 2015 (T1534 version) <ul style="list-style-type: none"> - Chem option, ocean/HYCOM option - Grell-Freitas cu option for seasonal, chem, NWP testing

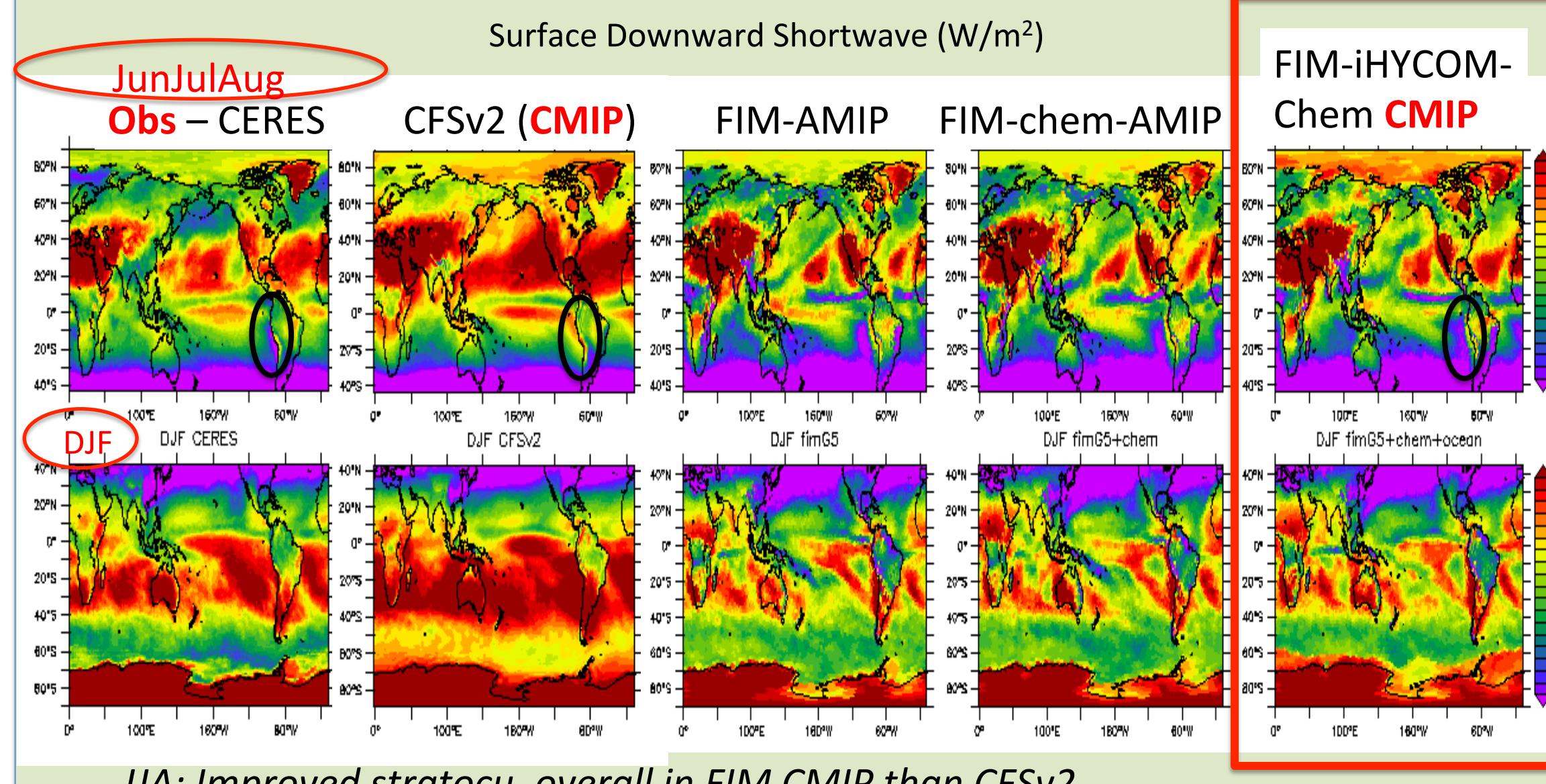
Results

Numerical Weather Prediction

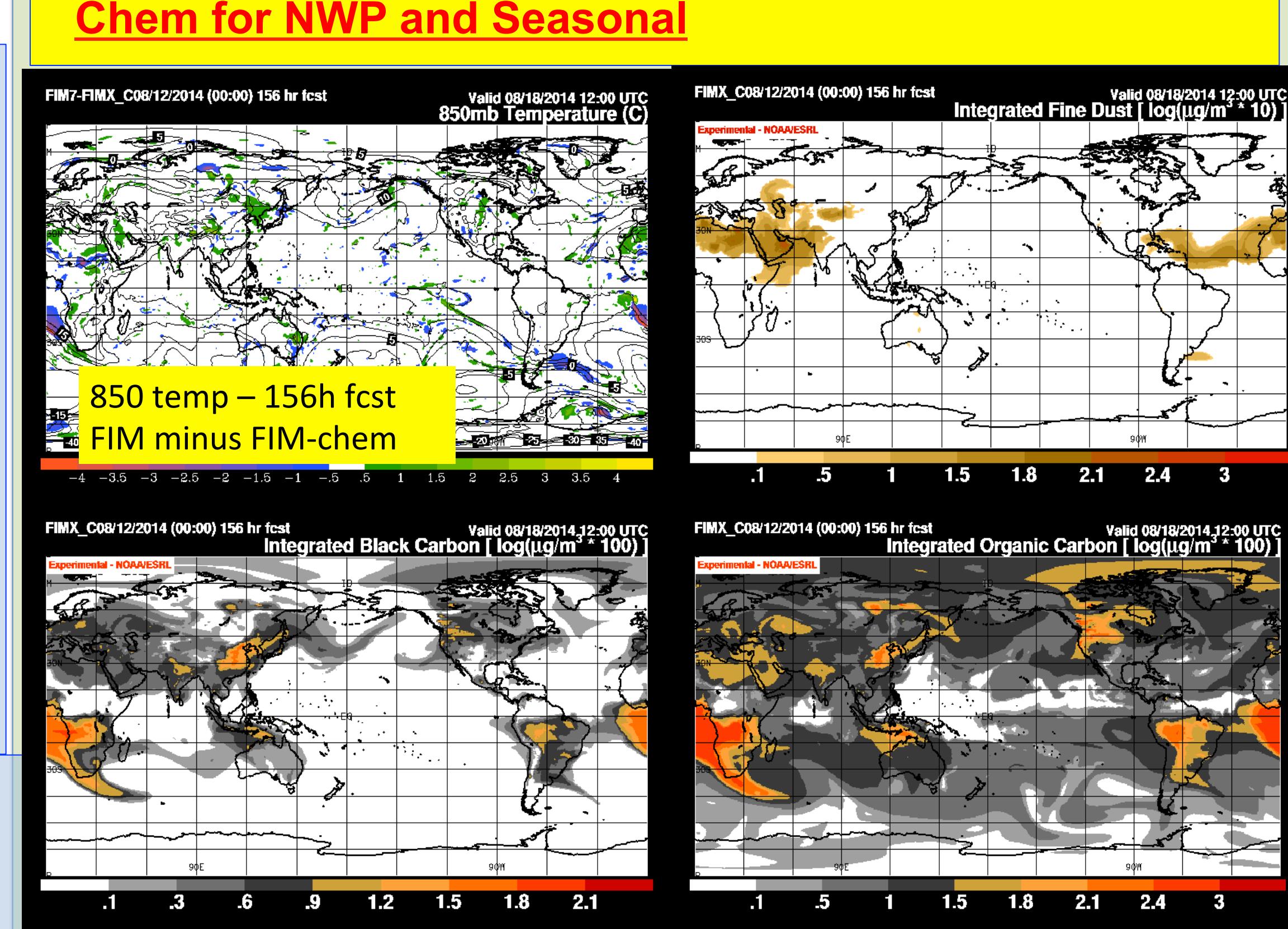


Seasonal

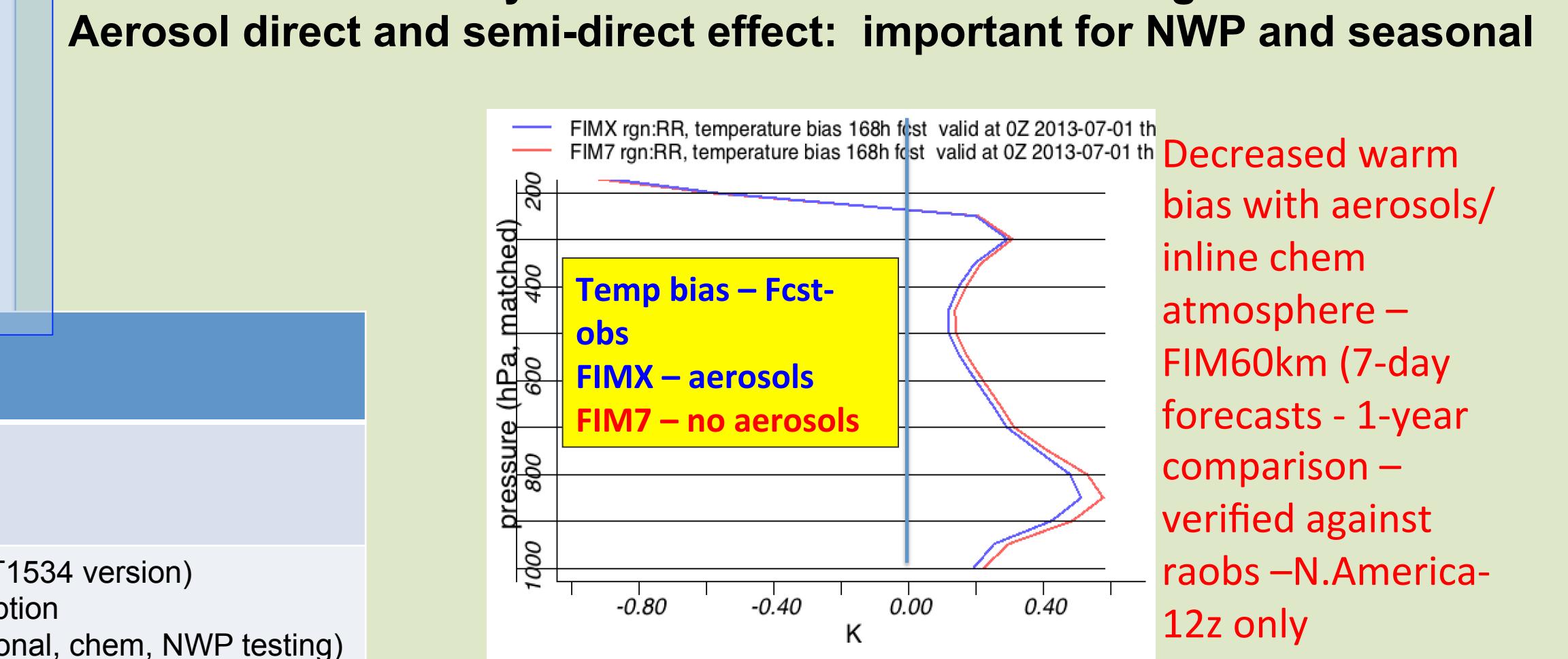
Coupled atmosphere/ocean – FIM240km forecast– 1-year



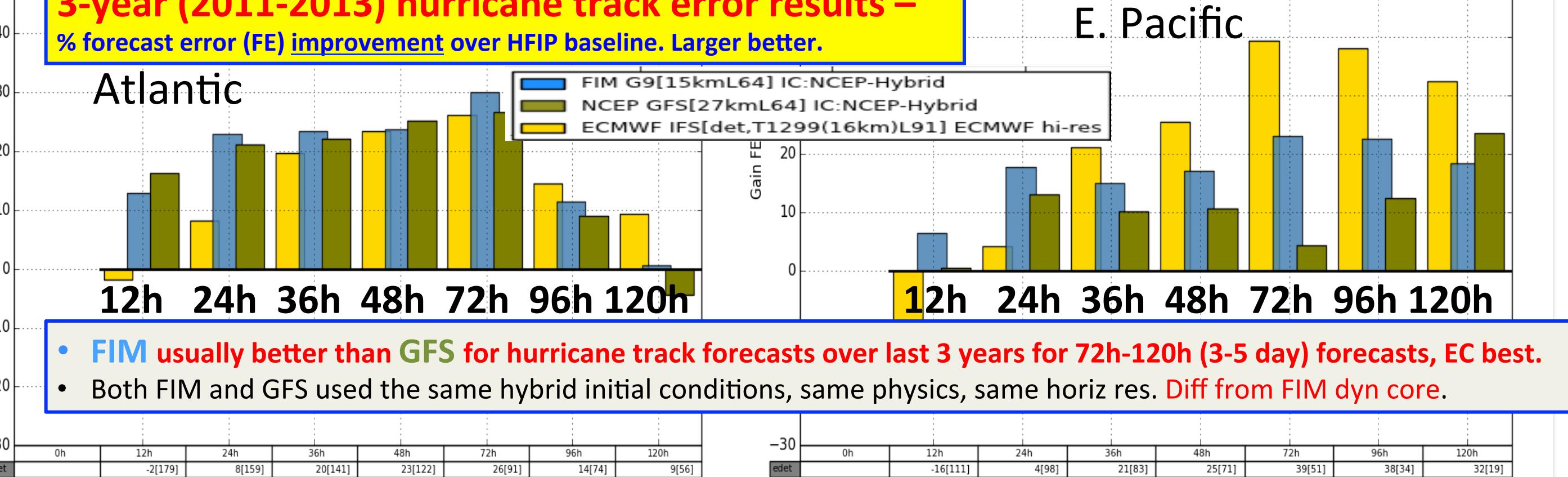
Chem for NWP and Seasonal



Case study: 156h fcsts valid 12 UTC 18 Aug 2014



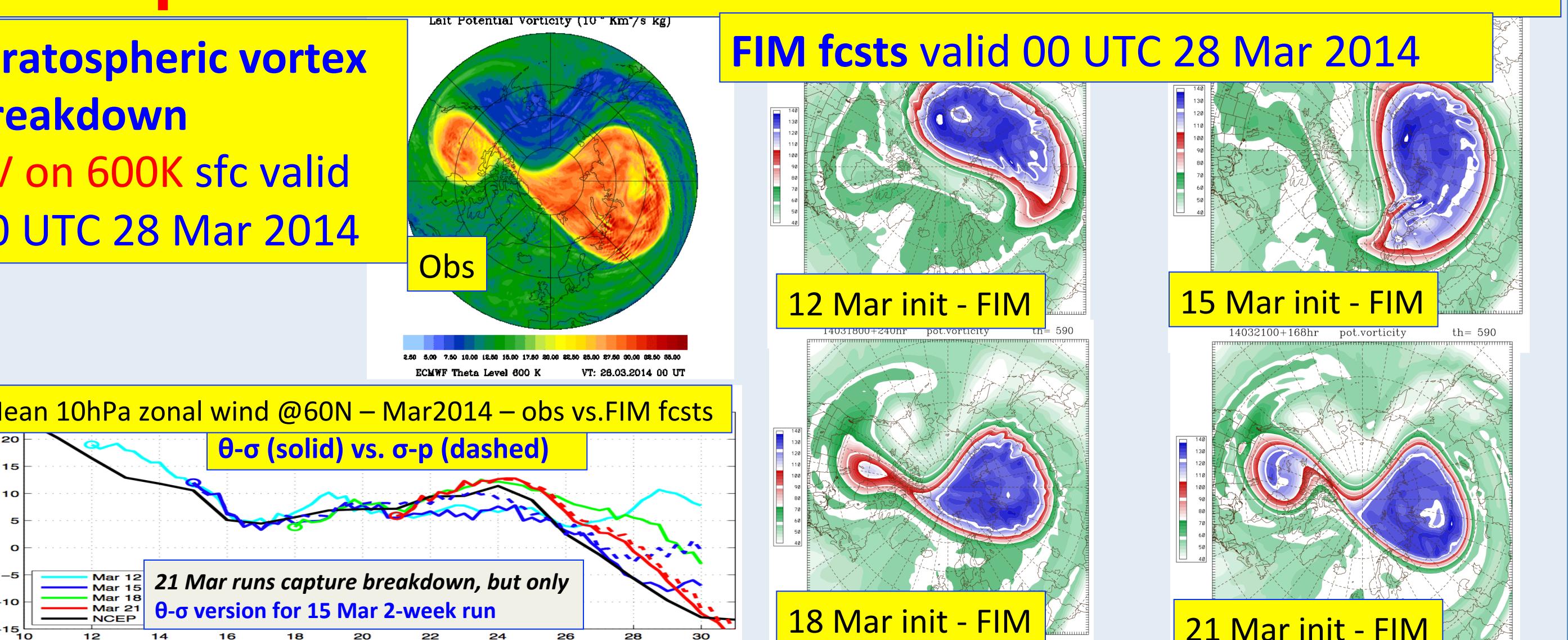
3-year (2011-2013) hurricane track error results – % forecast error (FE) improvement over HFIP baseline. Larger better.



Examples

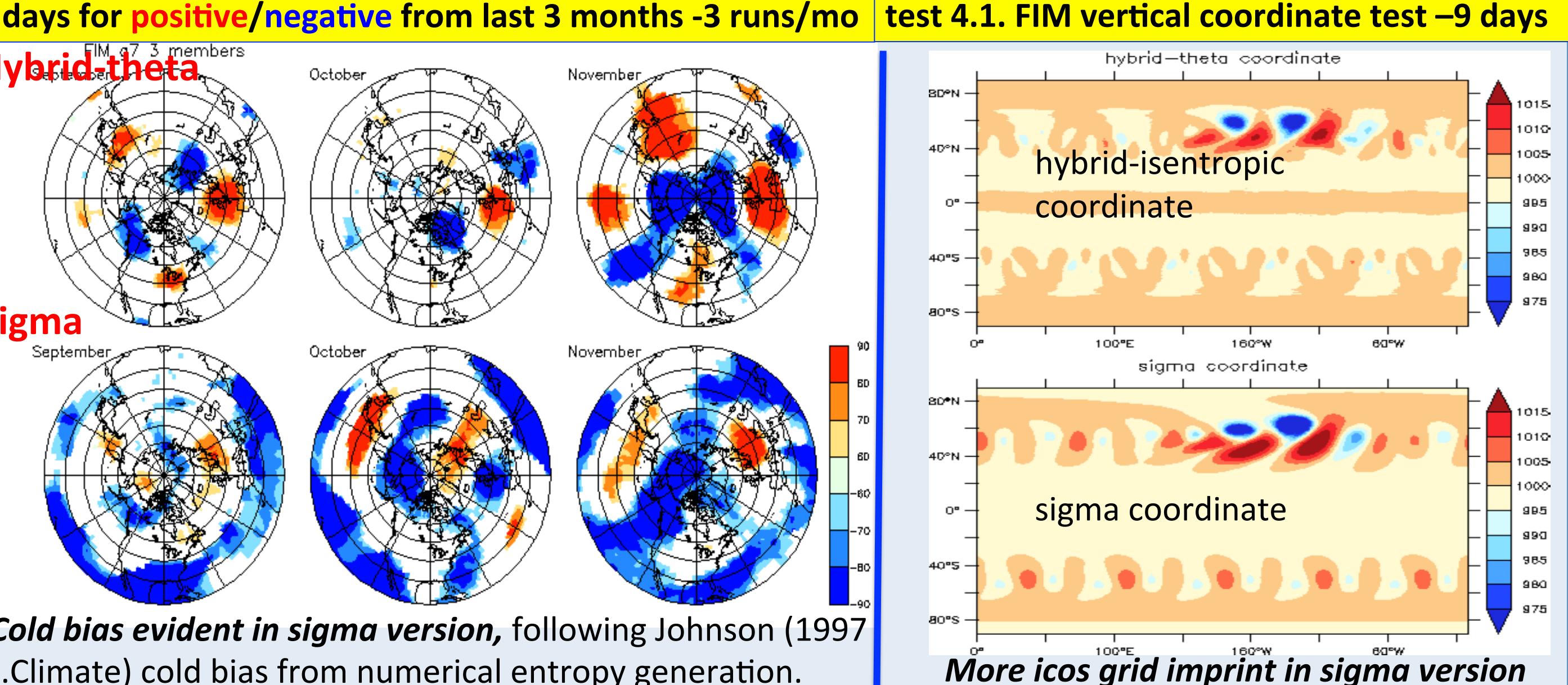
Stratospheric vortex breakdown

PV on 600K sfc valid 00 UTC 28 Mar 2014



FIM θ - σ (adaptive) vs. FIM σ - p (fixed) vertical coordinate

500 hPa height anomaly – 1-year AMIP tests – % days for positive/negative from last 3 months -3 runs/mo



Surface pressure in DCMIP baroclinic wave test 4.1. FIM vertical coordinate test -9 days

Current NWP activities and near future:

- HIWPP/NOAA project – provide improved experimental global forecasts to NOAA partners.
- HIWPP evaluation of FIM to provide multi-dycore diversity in NOAA Global Ensemble Forecast System (GEFS) and improve its skill.
- Provide baseline skill metric for future non-hydrostatic global models.
- Test advanced physics (scale-/aerosol-aware cumulus – Grell-Freitas, GFS EDMF PBL, MYNN PBL, others) in FIM but also in upcoming non-hydrostatic global dynamic cores.

Next coupled model/seasonal directions:

- Design and conduct NWP case study experiments using FIM, other models to answer:
 - To what extent is accurate prediction of processes (MJO, stratosphere, PV cons, etc.) necessary for predicting onset/cessation of stationary wave/blocking events?
- Conduct broader experiments with multi-year experiments with multiple global models for resolution/numerics sensitivity and 10-120km coupled atmos-ocean models (e.g., FIM-iHYCOM) under ESPC coordination with WWRP/WCRP P2P program)
- Provide NOAA/ESRL research tool with fully coupled atmospheric-ocean-chemistry model.
- Subseasonal-seasonal forecasting – participate in N.American Multi-Model Ensemble

Key aspects of FIM atm/ocean/chem model:

- Quasi-uniform horizontal unstructured grid - icosahedral
- Quasi-lagrangian vertical structure
- Scalable to 30,000 cores
- Contributes to NOAA coupled model capability including component interoperability with CFS/NCEP and GFDL.
- Adapt FIM-unique features to future global non-hydrostatic NWP/seasonal global coupled models.

Potential temp on PV=2 surface - 15km FIM model

72h forecast Valid 12z 30 Oct 2012 12h after landfall of Hurricane/Superstorm Sandy

